Quarterly Report
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A. Task Objective: Algorithm Development for Global Mapping of Phycoerythrin Pigment, Dissolved Organic Matter, and Chlorophyllous Pigment

1. MODIS North Atlantic Test Site Establishment and Characterization

As previously reported, the MODIS North Atlantic Test Site has been established as originally proposed. The Test Site includes the New York Bight/Mid-Atlantic Bight/Gulf Stream/Sargasso Sea and is conveniently located north and east of GSFC/WFF. Characterization has been initiated by ship sampling, aircraft overflights, and analysis of historical data available from within the NASA AOL project since 1980. Much of the data obtained in the northwestern portion of the test site will be used for algorithm development in Case 2 waters.

a. During this 3-month reporting period one airborne mission was flown in the MODIS Test Site and several are planned for the second quarter (April, May and June) in conjunction with ship cruises by University of Delaware scientists Dr's. Richard Geider and Jon Sharp and the cooperative efforts of MODIS Interdisciplinary Investigator, Dr. Niel Blough (WHOI). This airborne mission (and preliminary test flights) also allowed evaluation of the recently-rebuilt AOL system and will provide data needed to re-calibrate the fluorescence/Raman ratios derived from the AOL spectrometer data.

A manuscript describing some of the algorithm work was published during the previous reporting period. The reader should consult this paper for details of the progress of the DOM retrieval using fluorescence methods. The manuscript is: Hoge, Frank E., Anthony Vodacek, Neil V. Blough, "Inherent Optical Properties of the Ocean: Retrieval of the Absorption Coefficient of Chromophoric Dissolved Organic Matter from Fluorescence Measurements", Limnology and Oceanography, 38(7) 1394-1402, 1993. A paper describing the airborne retrieval of the CDOM absorption coefficient is now in press: Inherent Optical Properties of the Ocean: Retrieval of the Absorption Coefficient of Chromophoric Dissolved Organic Matter from Airborne Laser Spectral Fluorescence Measurements by Frank E. Hoge, Anthony Vodacek, Robert N. Swift and James K. Yungel, Applied Optics (in press 1995).

The airborne flights during April 1994 allowed the concurrent evaluation of a new 256 channel ocean color spectrometer designed and built at Wallops Flight Facility. It was found that the color sensor possessed the requisite sensitivity for ocean color spectra in a high-rate/low-integration-time mode needed to allow editing of data containing sun glint. The prototype sensor was

successfully flown during the JGOFS Iron Enrichment Experiments off the coast of Ecuador in November 1993. A still higher sensitivity detector and higher resolution sensor was successfully flown in March 1995. Preliminary evaluation of the data suggests that it is of good quality.

The evaluation of a sea surface temperature sensor manufactured by Heimann/EG&G was successfully continued from the previous two reporting periods. Our evaluation of this sensor suggests that the precision is satisfactory for support of the validation of MODIS products and algorithms relative to sea surface temperature. The final accuracy evaluation is still pending.

2. Selection of Case 1 Data Sets.

As given in a prior report, airborne active-passive ocean color data acquired within the MODIS Test Site with the NASA Airborne Oceanographic Lidar are continually being screened for use in algorithm development. The AOL active-passive data in the Middle Atlantic Bight (MAB) during April 1994 displayed remarkable quality and is the primary basis of the phycoerythrin retrieval by model inversion. Other data sets are also under evaluation.

B. Other Work Accomplished

1. Revision of the Algorithm Theoretical Basis Document (ATBD).

ATBD revision 1 is now complete and is available electronically. The original (and the revised) document details a new procedure for retrieving the phycoerythrin pigment by using the absorption bands. Existing MODIS bands are expected to be sufficient to effect the retrieval.

2. Ship Data.

As reported in the above sections and referenced papers, recovery of the absorption coefficients for the light-absorbing or chromophoric components of the dissolved organic matter (aCDOM) from their fluorescence emission has been established by laboratory analyses of surface samples gathered from several ship cruises. These absorbance and fluorescence analyses, (and work reported by others), show that absorption coefficients in the near ultraviolet can be directly retrieved from measurements of the fluorescence emission of CDOM. Thus, absorption coefficients in the entire visible spectrum can be obtained since the CDOM absorption is rather faithfully represented as a exponential function of wavelength. The errors in the laboratory fluorescence measurements were minimized through the combined use of water Raman scatter as an internal radiometric standard and a quinine sulfate solution as a reference. This methodology reduces aCDOM algorithm retrieval errors (reported by other researchers) primarily attributable to the use of commercial spectrophotometers having maximum optical path lengths of 10 cm. While the aCDOM

retrieval appears feasible, the relationship between aCDOM and CDOM fluorescence emission is susceptible to changes in CDOM fluorescence yield and the ratio of CDOM to the nonchromophoric DOM fraction of the total DOM. So the continued temporal study of marine samples from many diverse oceanic locations is needed. When applied to shipboard and aircraft laser fluorometers, this retrieval methodology and the resulting CDOM absorption coefficients will be used in ocean color models and associated satellite sensor/algorithm development directly aimed at phycoerythrin retrieval. The DOM is important since it is a major interferant to the detection and quantification of chlorophyll and chlorophyll accessory pigments (CAP) such as phycoerythrin. Moreover, DOM is a contributor to the carbon cycle itself.

2. In Situ Optical Characterization of the MODIS North Atlantic Test Site.

The continued characterization of the Test Site is partially described in the previously mentioned publications.

A. As briefly mentioned before, cooperative overflights within the MODIS Test Site were conducted during March, 1995 in conjunction with shipboard CDOM sampling activity conducted by Dr's. Richard Geider and Jon Sharp (both of Univ. Del.) and the cooperative efforts of MODIS Interdisciplinary Investigator, Dr. Niel Blough (Univ. MD). We expect to obtain flow cytometry data from Dr. William Li of the Bedford Institute of Oceanography (Canada) and HPLC data from U. Md. Horn point Environmental laboratory.

1. Phycoerythrin Algorithm Development Activities

Plans call for us to again directly address the quantification of the phycoerythrin signal as outlined in the original MODIS proposal. The phycoerythrin retrieval is being dealt with by inversion of ocean radiance models. Details of the phycoerythrin retrieval appear in the ATBD as submitted the project office.

2. Chlorophyll Pigment and CDOM Corrections to the Phycoerythrin Algorithm.

Major perturbations or influence to the ocean color spectrum are provided by chlorophyll and CDOM. These oceanic constituents significantly impede the retrieval of phycoerythrin pigment from the upwelled radiances. Accordingly, they must be dealt with in a systematic way in order to understand their effects and the impact on the retrieval of phycoerythrin and its ultimate quantification. In situ and airborne data gathered to date will be used to model the effects and to ascertain the extent to which they can be quantified and removed. Recently published chlorophyllous pigment models are being used to estimate the pigment absorption. Our own CDOM model is being used for recovery of chromophoric dissolved organic matter. Finally, the literature is being surveyed for the best available detritus absorption model. The most pressing modeling problem is the availability of suitable chlorophyllous

and nonchlorophyllous particulate backscatter models. This problem is being addressed by : (1) closer interaction with researchers from the Stanford Research Institute (Dr. Robert Maffione) and the Johns Hopkins University / Applied Physics Laboratory (Dr. Jeff Smart and Dr. Daniel Ondercin). These institutions are leaders in the measurement of oceanic particulate backscatter. Data is now being transferred from JHU/APL for analysis. The SRI backscatter sensor is to be deployed during future ship cruises being overflown by the NASA/AOL active-passive system.

3. Other Data Acquisition for Algorithm Development

After the conclusion of the cooperative flights in April 1995, additional MODIS test flights are to be conducted in early June 1995 in the MODIS Test Site to prepare for airborne missions during the JGOFS Arabian Sea Experiment.

C. Anticipated Activities During Next Quarter.

1. Preparations are being made to participate in the JGOFS Arabian Sea Experiment in July 1995. This is an opportunity to obtain data in an entirely different oceanic province. As was the case with the Iron Enrichment Experiment flights, these flights will serve as a valuable data source for algorithm development. This activity should contribute to the goal for universality of the algorithms being developed.

D. Other Concerns

RTOP funds from HQ provide the foundation support of the AOL instrumentation. The anticipated reduction of these funds will severely hamper the MODIS efforts herein, especially validation planning and eventual field execution efforts.

As in a past report some good news is reportable. The lack of a 600nm band on MODIS-N was given as the biggest problem facing the retrieval of the phycoerythrin pigment on the first sensor launch. Recent studies of available radiance (and reflectance) models, however, suggests that the retrieval of the phycoerythrin pigment at the absorption peaks of 495nm (phycourobilin, PUB) and 545nm (phycoerythrobilin, PEB) can be achieved using the 490nm and 555nm MODIS bands. Such retrievals will require a highly accurate model to account for the significant amounts of chlorophyll and DOM absorption occurring simultaneously with the phycoerythrin absorptions. The details of the phycoerythrin retrieval have been recently detailed in the ATBD.